

UNLOCKING HIDDEN POTENTIAL OF SHALLOW RESERVOIR AT 1955-2342 mSS, IN RUHOUL FIELD

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Abstract

As a human, live in the ever-changing environment, with the abundant amount of human movement, increasing population, and advancing technology, consuming high energy is inevitable. Indonesia has been working to obtain better energy to fuel the world. As the multinational energy company, Pertamina Hulu Mahakam, located in East Kalimantan, operate world wide to extract oil and gas from the reservoir in Mahakam Delta, which already used high technology and qualified human resource to support the safe, efficient, and effective production process.

The petroleum system models, the contribution of marine shales to the generation of liquid and gaseous hydrocarbons in the Mahakam was considered negligible. The production of the oil fields has started quite early, however the major development phase of gas accumulation started within the last decade, with increasing activity since.

Ruhoul is an offshore gas field belongs to Pertamina Hulu Mahakam that located in Mahakam Delta, East Kalimantan, Indonesia. It covers an area of 350 km² and has a gross thickness of the payzone over 2000 m. Structural architecture of Ruhoul field is multilayered un-faulted anticline. Stratigraphically, Ruhoul reservoirs are divided into two intervals which are Ruhoul Main Zone and Ruhoul Shallow. This study is only focused in Shallow zone area, they are Sh-8a, Sh-8c, and Sh-8d, as it is considered as remaining prospective area for Ruhoul field. For more specific, Sh-8a was produced by wells RJ-16A-M and RJ-2G-M.T3, Sh-8c was produced by well RJ-2G-M.T3, and Sh-8d was produced by well RJ-2G-M.T3.

Over time, the gas production in Ruhoul Field keep decreasing, therefore hidden gas production potential needs to be re-evaluated. The evaluation can be done by doing the dynamic synthesis analysis based on completion type used, production history, and well correlation.

The main objective of this study is to evaluate hydrocarbon potential in Ruhoul Shallow specific area. Several approaches will be used to assess Ruhoul Shallow zone prospect such an updated database, zone change inventory, and well correlation based on netpay map by layer with software Geolog 7.2.

Perform Dynamic Synthesis Analysis and P/Z Straight Line Material Balance Calculation are chosen as the methodology to assess the prospect zone of this field. The results of this process are candidates to be the re-opening zone, the value of GIIP, EUR, RR, RF, also the drive mechanism applied to each layer. Not only that, the results also obtained the Plateau rate stage curve in each layer.

The results showed two categories of re-opening candidates, P/Z methodology to calculate the value of GIIP and RF, and Plateau stage in each layer. Along with this study, the only well that suit to be the candidate for re-opening zone was only RJ-2G-M.T3 in Sh-8a, while the other layers and wells were not suit to be the candidate for re-opening zone. From the P/Z Straight Line calculation, the GIIP for the candidate (Sh-8a produced by RJ-2G-M.T3) is 1.15 BSCF, with 1.02 BSCF Gp max, and 89% RF, and has depletion drive as its drive mechanism. Based on Plateau stage with 4 MMSCFD as the plateau rate, the decline in RJ-2G-M.T3 (Sh-8a) started on July 2015.

Keyword: Dynamic Synthesis Analysis, P/Z Straight Line, Plateau Rate Stage

I. INTRODUCTION

As the growing of gas demand in the future, it is necessary to find additional reserves and maintain the production capacity of Ruhoul field by developing area around it and assessing the lateral limitation of the field. Ruhoul Shallow zone is considered as a remaining prospective area for Ruhoul field. With Dynamic Synthesis Analysis, the hidden potential of the shallow zone of Ruhoul field would be discovered. There was an unusual case in this study, the way to correlate the wells was to correlate the main well to its surround well. It is because Ruhoul Shallow has a lenses reservoir based on the netpay map per layer. Recently, all recent well data also need to be integrated in Ruhoul Shallow zone for a valid prospect evaluation.

II. GENERAL REVIEW

2.1. Ruhoul Field Location

Ruhoul is a gas field firstly discovered in 1983 with exploration well RM-1. 192 wells have been drilled and produce from Ruhoul field. Producing from 8 platforms with approximately ± 100 standard cubic feet per day of gas produced and more than thousand barrel per day of oil and condensate gas. Cumulative gas produced as in 31 December 2015 is more than 1 billion cubic feet. Ruhoul field is an offshore gas field. It is because of the reservoir temperature is above the critical temperature of the hydrocarbon fluid, so the reservoir is considered as a gas reservoir. Ruhoul offshore gas field located 25 km South-East of Maria. Ruhoul field production start-up started in December 1999.

2.2. Dry Gas

The reservoir character in Ruhoul Shallow is Dry

Gas Reservoir, based on the phase diagrams and the prevailing reservoir conditions. Mostly, a system having a gas-oil ratio greater than 100,000 scf/STB is considered to be a dry gas.

Dry gas reservoir characterizes as the hydrocarbon mixture exists as a gas not only in the reservoir but also in the surface facilities. Water is the only liquid associated with the gas from a dry gas reservoir. The classification of hydrocarbon fluids might be also characterized by the initial composition of the system. The heavy components in the hydrocarbon mixtures have the strongest effect on fluid characteristics. (Jr. W. D., 1994).

2.3. The Material Balance Method

The Initial Gas In Place (GIIP or G), the initial reservoir pressure (Pi), and the gas reserves can be calculated without knowing the area (A), height (h), porosity (Ø), or water saturation (Sw), if enough production history is available for a gas reservoir. In general, dry gas reservoirs can be classified into two categories, volumetric gas reservoirs and water-drive gas reservoirs. (Ikoku, 1984).

In terms of P/Z calculation, the calculation expressed by:

$$\frac{P}{Z} = \frac{P_i}{Z_i} - \left[\frac{P_{sc} T}{T_{sc} V} \right] G_p \quad (1)$$

Gp	= Cumulative Gas Production (BSCF)
P	= Pressure (Psi)
Pi	= Initial Pressure (Psi)
Psc	= Critical Pressure (Psi)
T	= Temperature (degR)
Tsc	= Critical Temperature (degR)
Z	= Gas Compressibility Factor
Zi	= Gas Compressibility Factor at Pi

2.4. Production Report Based on Dynamic Synthesis Methodology

Every details of production history is needed to perform dynamic synthesis analysis. Those steps started from updating field data base, and continue to correlating wells with Geolog 7.2 software (based on netpay map per layer), collecting some data from well diagram, production test history, well chronology, and direct viewer, to specifically analyze the well. The last step in this project is to categorizing which zone that is suit to be the candidate for re-opening and which that is not, and calculating the value of Initial Gas In Place (GIIP), Remaining Reserves (RR), Estimated Ultimate Recovery (EUR), Recovery Factor (RF), and the plateau stage in each layer.

2.5. Estimated Ultimate Recovery (EUR)

An EUR is an estimate of the expected ultimate recovery of oil or gas from a producing well. Several methods are used to estimate an EUR, and the methods differ depending upon the purpose of the study. (Cook, 2005). In other words, EUR is an

approximation of the quantity of oil or gas that is potentially recoverable or has already been recovered from a reserve or well. The equation to calculate the EUR explained below:

$$EUR = GIIP \times RF \quad (2)$$

EUR	= Estimated Ultimate Recovery (BSCF)
GIIP	= Initially Gas In Place (BSCF)
RF	= Recovery Factor (%)

2.6. Recovery Factor (RF)

Recovery factor (RF) is the overall proportion of oil and gas expected to be extracted, in other words RF is the percentage of the hydrocarbon in place that can be produced with each production plan.

2.7. Gas Sales and Purchase Agreement (GSPA)

The Gas Sales and Purchase Agreement (GSPA) is a standard agreement for the sale and purchase of natural gas for delivery into a pipeline network or to a facility such as a power station, factory or LNG (Liquefied Natural Gas) liquefaction plant. The GSPA represents a balanced document containing a range of alternative treatments of common issues for the parties to select from and additional optional clauses for incorporation if required. (AIPN, 2006).

In Daily Contract Quantity (DCQ), there are some different daily quantities during build up, plateau, and decline period. (Bansal, 2017).

- Build up – period is the agreed daily contract quantities during build up period. For example, the agreed quantities during build period may be like 40% of plateau period DCQ (within 6 months) and 60% of plateau period by the first year.
- Plateau – period is the agreed fixed DCQ during plateau period. This can last for a fixed period of timing or alternatively, plateau DCQ can continue until a fixed proportion of reserves on the field have been produced.
- Decline – period is after plateau period production continues to decline until abandonment. At this time the DCQ will be reset each year depending upon the field production capacity. The seller will nominate a decline DCQ to the buyer each year using a specified notice period laid down in the contract.
- In decline contracts, an annual fraction of committed gas reserves is very common for setting contract quantity. If a calculation from reserves is used, the contract should have a clear procedure for determining reserves, including resolving disputes over reserves between the buyer and seller.

III. RESEARCH METHODOLOGY

To determine whether the well is suit for re-opening zone or not, updating the field data base is the first thing to do in order to validate the source of the analysis. The summary of the complete methodology applied in Figure 1.

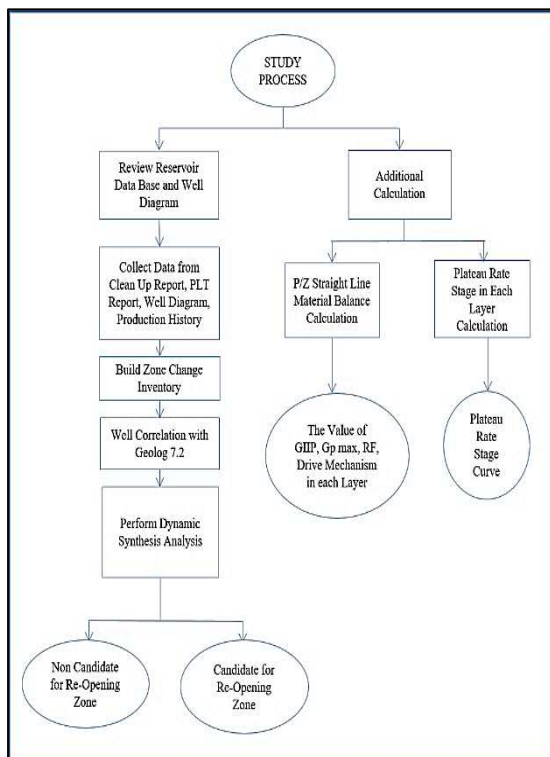


Figure 1. Flow Chart of The Project

The analysis was performed using some softwares such as MS Excel 2010, I-ServeWell (well diagram report, well chronology report, and direct viewer report), Geolog 7.2, and Ruhoul-field data bases. The analysis is subdivided into four parts.

The first part is to review the perforation history of the well to ensure the data bases. In this part, some data were compared between reservoir data-base and well diagram. Those compared-data were perforation date, top and bottom perforation depth, and well completion type. If those compared data are match with each other, the job can move to the next step. The second part is to build the zone change inventory in order to ease the dynamic synthesis analysis, this part was made by summarize the conclusion from Clean Up report, PLT report, and I-ServeWell that contents well diagram and well chronology from each well. The third part is to perform the dynamic synthesis analysis. Ruhoul data base, production test history, zone change inventory, well diagram, well chronology, direct viewer report, netpay map by layer, and well correlation by Geolog 7.2, were needed to analyze the dynamic synthesis. In order to complete the analysis, the correlation method is done by correlating the focused well to its surrounding wells, based on netpay map per layer. The last part is to determine the result of unlocking hidden potential of ruhoul field shallow reservoir, whether the well with specific layer is suit to be the candidate for re-opening target or not. The results from this part are subdivided into two categories, candidate for re-opening well and non candidate for re-opening well. Not only that, but the results also obtain the

value of GIIP, RF, Gp max, and the plateau rate stage curve.

IV.RESULT AND ANALYSIS

4.1 Dynamic Synthesis Analysis Results

The result from this study, categorize in two. The first one is the non-candidate for re-opening zone, and the second one is the candidate for re-opening zone. Based on the result, there was only RJ-2G-M.T3 in layer Sh-8a that suits the criteria to be the next candidate for re-opening zone. The results from the analysis summarized in Table 1 and 2.

Table 1. Next Perforation Target Results

Next Perforation Target	Correlated With	Layer
RJ-3A-M	RJ-16A-M	Sh-8a
RJ-104G-M.G1	RJ-2G-M.T3	Sh-8a
RJ-104G-M.G1	RJ-2G-M.T3	Sh-8c
RJ-17G-M	RJ-2G-M.T3	Sh-8c
RJ-10G-M	RJ-2G-M.T3	Sh-8d

Table 2. Dynamic Synthesis Analysis Result

Re-Opening Zone Candidate Result		
Well Name	Layer	Result
RJ-16A-M	Sh-8a	Non Candidate
RJ-2G-M.T3	Sh-8a	Candidate
RJ-2G-M.T3	Sh-8c	Non Candidate
RJ-2G-M.T3	Sh-8d	Non Candidate

4.2 GIIP and RF Calculation by P/Z Straight Line Material Balance

Based on the data availability, Ruhoul Field used the P/Z Straight Line Material Balance as the calculation method to got the GIIP and RF result in each layer, that were Sh-8a, Sh-8c, and Sh-8d. Make a plot by the data sources, that contains Pressure and Z factor which next will be the source to get a mathematical equation (y) that calculated with the help of Microsoft Excel. The curve is shown in Figure 2, from the calculation in the curve, the value of y, expressed by:

$$y = 3E-08x^2 - 0.0001x + 1.0036 \quad (4)$$

Based on the Eq. 5, the value of y represents the value of Z, while the value of x represents the value of P. This mathematical equation (y), will be used as the source equation to calculate the GIIP and RF in each layer, Sh-8a, Sh-8c, and Sh-8d. Before calculate the goals in this study, ensure the availability of any needed data, such as P, Q, Gp, and Cumulative production in every layer.

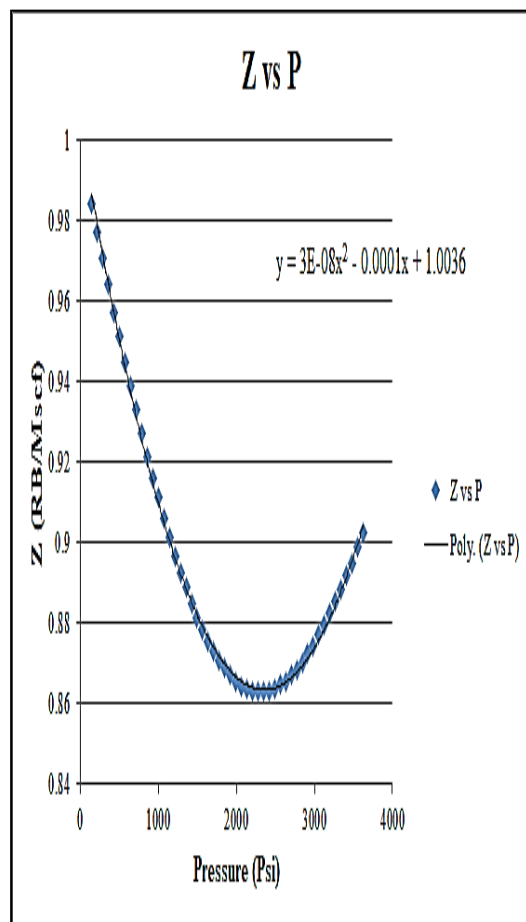


Figure 2. Z vs P Curve

Before proceeding to the next step, calculate the value of Z of field abandoned pressure, which was 450 Psi. The calculation is based on the trend-line equation (Eq. 5). The x variable in the equation functioned as abandoned pressure, while the y variable functioned as the value of z. The P/Z calculation for abandoned pressure showed in Table 3.

Table 3. P/Z Calculation at P abandoned

P abandoned (Psi)	450
Z	0.964675
P/Z abandoned	466.4783

The calculation of P/Z at P abandoned will be used to determine the value of G_{max}, RF, and Drive Mechanism of each layer.

Table 4. Contains the information about each layer, that are Sh-8a, Sh-8c, and Sh-8d. To get the result of Z, use the calculation by Eq.5. After the value of Z is known, start to divide between P and Z. All of this information is based on the previous data base.

Table 4. P/Z Calculation Result in Each Layer

Layer	Sh-8a		Sh-8c		Sh-8d	
T	2013	2018	2015	2015	2015	2015
Q (Bcsf)	0.46	0.00	0.30	0.02	2.2	0.2
G _p (Bscf)	0.46	0.741	0.30	0.32	2.2	2.4
P (Psi)	2435	166.7	2435	1600	2453	1600
Z	0.9379	0.987	0.937	0.920	0.93	0.92
P/Z	2596	168	259	1738	2612	1738.3

Plot P/Z (Y axis) and G_p (X axis) in each layer to get the trendline equation (y), which will be used to know the value of G_{HP} in each layer (y=0). Based on the calculation, the curve expressed in Figure 3 through 5.

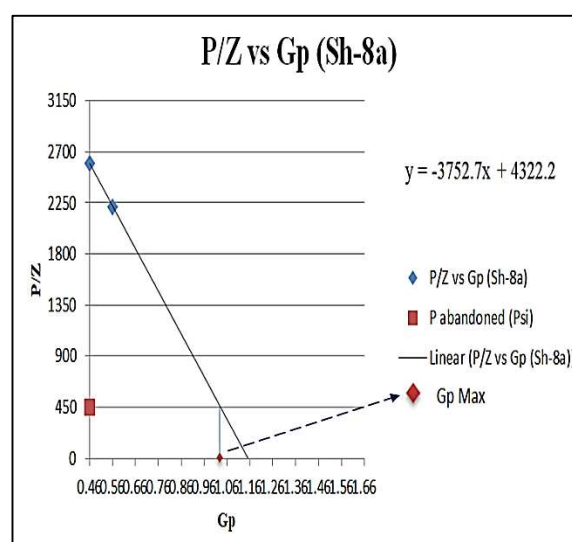


Figure 3. P/Z vs Gp in Sh-8a

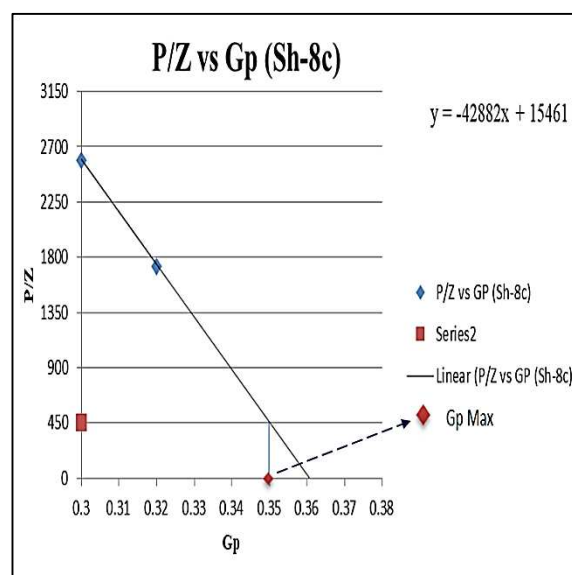


Figure 4. P/Z vs Gp in Sh-8c

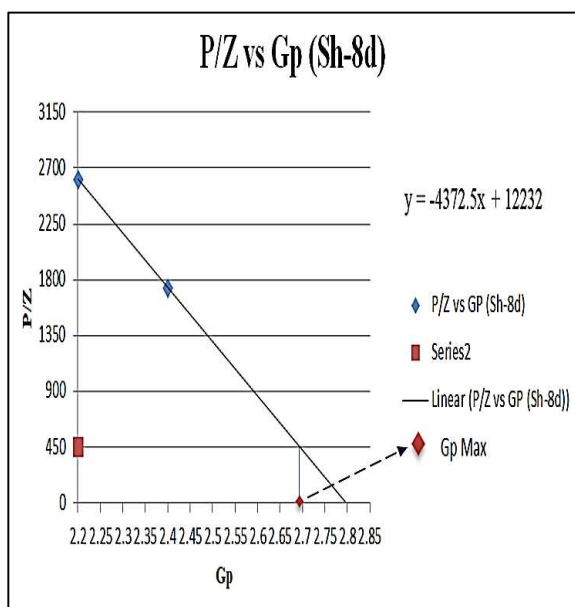


Figure 5. P/Z vs Gp in Sh-8d

Based on the curve that expressed in Figure 3 through 5, the trendline equation in each layer, expressed by:

- Sh-8a
 $y = -3752.7x + 4322.2$ (5)
- Sh-8c
 $y = -42882x + 15461$ (6)
- Sh-8d
 $y = -4372.5x + 12232$ (7)

With the relationship with P/Z abandoned, the results about GIIP, Gp max, and Drive Mechanism in each layer can be found. In short, the results sum up in Table 5.

Table 5. P/Z Calculation Result in Each Layer

Layer	Sh-8a	Sh-8c	Sh-8d
GIIP (Bscf)	1.1517	0.3605	2.7974
P/Z abandoned	466.4783	466.4783	466.4783
Gp max (Bscf)	1.0274	0.3496	2.6908
RR (Bscf)	0.2862	0.0734	0.6840
RF (%)	89%	97%	96%
Drive Mechanism	Depletion Drive	Depletion Drive	Depletion Drive

As shown from the result of dynamic synthesis analysis result, the candidate that suit to be re-opening zone is from layer Sh-8a, well RJ-2G-M.T3. Based on the P/Z method, Sh-8a got the smallest RF among Sh-8c and Sh-8d. Sh-8a with 89% RF, Sh-8c with 97% RF, and Sh-8d with 96%

RF. The highest GIIP was 2.79 BSCF that belongs to Sh-8d, and 1.15 BSCF that belongs to Sh-8a, and 0.36 BSCF that belongs to Sh-8c.

In conclusion, despite the fact that Sh-8c and Sh-8d were bigger in every details of forecast than Sh-8a, it does not mean that the layer with bigger rate can be produced smoothly. There are a lot of parameters to decide whether the well is prospect enough to be produced again or not. One of the way is to perform dynamic synthesis analysis, followed by the P/Z Straight Line Material Balance calculation, and The Plateau rate stage in each layer.

4.3 Plateau Stage

Ruhoul field has it owns of Model Gas Sales and Purchase Agreement (GSPA). The advanced production phase is known as stabilization stage, or known as Plateau. This stage is related to the maximum production that can be produced by a field. The plateau rate for Ruhoul shallow reservoir is 4 MMSCFD. The rate of the gas will stay in plateau condition when it reached 80% of EUR or GP max while the rate will be declined at 20% of EUR. Due to this project only focused on some layers in Ruhoul Field, thus the GSPA can not be analyzed perfectly. Nonetheless to make it simple, there is a way to still know the Plateau rate in each layer by making the report on Microsoft Excel.

Table 6. Contains all of the information in each layer to make a plateau rate curve. Company has their own plateau rate, in this case the plateau rate of the Ruhoul field is 4 MMSCFD. Input every data that needed to be calculate to make a plateau curve. The goal is to know how long the layer can be produced commercially.

Table 6. Plateu Rate Stage Calculation

Layer	Sh-8a	Sh-8c	Sh-8d
EUR (Bscf)	1.0274	0.3496	2.6908
Qgas Initial (Mmscfd)	4	4	4
Start Decline (% of EUR)	80%	80%	80%
Plateau Stage (months)	7	5	18

After calculating those data needed in each layer (Table 6.) and the production data, plot the curve between Qgas, Time, and Gp. The result of the Plateau Rate Stage will be easier to see and analyze.

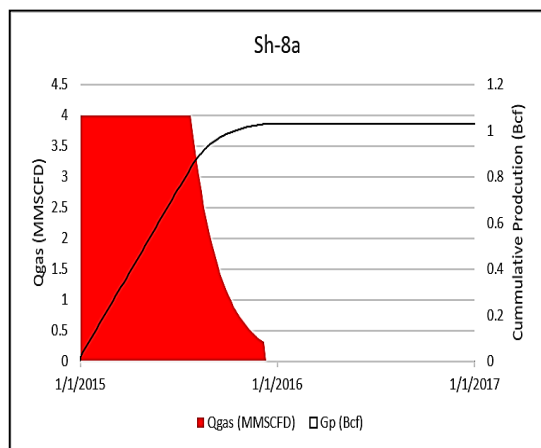


Figure 6. Plateau Rate Stage Curve in Sh-8a

As seen in Figure 6., the plateau of the Qgas started it declined on July 2015, while the Qgas started it declines, the rate of Gp started it plateau stage.

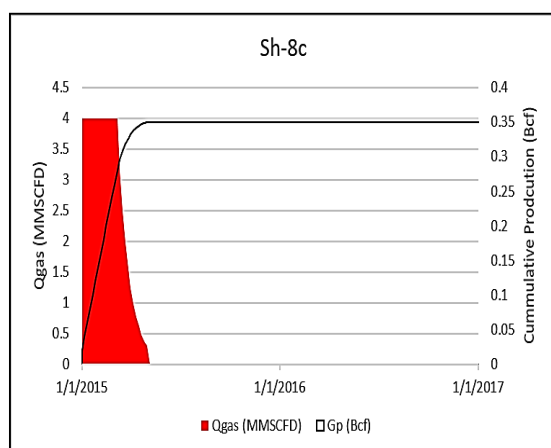


Figure 7. Plateau Rate Stage Curve Rate in Sh-8c

Figure 7. showed the plateau stage in Sh-8c, the plateau of the Qgas started it declined on May 2015, while the Qgas started it declines, the rate of Gp started it plateau stage.

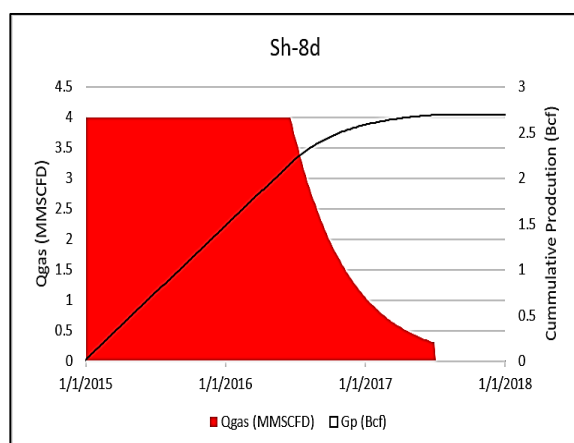


Figure 8. Plateau Rate Stage Curve in Sh-8d

As shown in Figure 8., the plateau of the Qgas started it declined on June 2016, while the Qgas started it declines, the rate of Gp started it plateau stage.

V. CONCLUSION

From this project, the hidden potential of shallow reservoir in layer Sh-8a, Sh-8c, and Sh-8d, located in Ruhoul Field, which involved two wells that are RJ-16A-M and RJ-2G-M.T3 were unlocked by some methods. To sum up, the conclusions listed below:

1. From Ruhoul Shallow Dynamic Analysis, RJ-16A-M (in Sh-8a) and RJ-2G-M.T3 (in Sh-8c and Sh-8d), are not suit to be the candidate for re-opening zone. However, RJ-2G-M.T3, Sh-8a, is suit to be the candidate for re-opening zone.
2. Apart from the result of re-opening target, 4 reservoirs for Next Perforation Target Candidates were identified based on well correlation by Geolog 7.2, they were RJ-3A-M, RJ-104G-M.G1, RJ-17G-M and RJ-10G-M.
3. Based on P/Z method, Sh-8a has an initial gas in place 1.15 BSCF, 1.02 BSCF Gp max, 0.2862 BSCF remaining reserves, and recovery factor 89%. Furthermore, Sh-8c has an initial gas in place 0.36 BSCF, 0.34 BSCF Gpmax, 0.0734 BSCF remaining reserves, and recovery factor 97%. And last, Sh-8d, with initial gas in place 2.79 BSCF, 2.69 BSCF Gp max, 0.6840 BSCF remaining reserves, and recovery factor 96%. The high percentage of RF indicates that the drive mechanism in each layer is depletion drive.
4. Although the fact that Sh-8c and Sh-8d were bigger in every details of forecast than Sh-8a, it doesn't mean that the layer with bigger rate can be produced smoothly. There are a lot of parameters to decide whether the well is prospect enough to be produced again or not. One of the way is to perform dynamic synthesis analysis.
5. Plateau rate in Ruhoul shallow field is 4 MMSCFD that goes through 80% EUR. The Qgas decline in Sh-8a started on July 2015 (7 months plateau), Sh-8c started on May 2015 (5 months plateau), while Sh-8d started on June 2016 (18 months plateau).

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